Improved Water Vapor and Ozone Profiles in SRT AIRS Version 6.X

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Background

This research is a continuation of previous AIRS Science Team work now being done under the proposal "Upgrade and Maintenance of the AIRS Version-6 Retrieval Algorithm".

AIRS Version 6 was finalized in late 2012 and is now operational Version 6 contained many significant improvements in retrieval methodology compared to Version 5:

- Surface skin temperature and spectral emissivity retrieval
- $T(p)$ retrieval
- Improved error estimates and their use for QC purposes
- Improved cloud parameter retrievals
- Improved OLR RTA

Version-6 retrieval methodology used for the water vapor profile $q(p)$ and ozone profile $O_3(p)$ retrievals is basically unchanged from Version 5, or even from Version 4.

Short Range SRT Plans for Version 7
as Taken from March 2014 Science Team Meeting

- Re-optimize details of all retrieval steps

  Most optimization previously done used 2 regression start up state

  $q(p)$ retrieval had not been modified since Version 4

  Version 6 $q(p)$ retrieval degrades Neural-Net guess $q^0(p)$

- We have already made significant improvements in $q(p)$ retrieval methodology in our current SRT

Improved $q(p)$ results were demonstrated at March 2014 Science Team Meeting.

At that time, I verbally recommended that we consider reprocessing all AIRS data with further improved retrieval methodology in the relatively near future – say mid to late 2015 – if new results show that it would be worthwhile. Further reprocessing with a full-up Version 7 retrieval methodology could wait until 2016 or 2017.

Version 6.X

John Blaisdell ran Version 6.X at JPL for all of August 2013

Version 6.X includes all previous changes made to the $q(p)$ retrieval:

- Modified Neural-Net $q^0(p)$ guess above the tropopause
  Linearly tapers the neural net guess to match climatology at four fine levels above the tropopause
- Changed the 11 trapezoid $q(p)$ perturbation functions used in Version-6 so as to match the 23 functions used in $T(p)$ retrieval step
- Increased the damping used in $q(p)$ step because we now have more functions

Version 6.X also includes new changes made to the $O_3(p)$ retrieval step as well as an increase in the number of stratospheric channels used in the $T(p)$ retrieval step. This new research was a consequence of discussions with Gordon Labow, in the Atmospheric Chemistry and Dynamics Branch at GSFC, who has been looking into the possibility of augmenting the OMI total O_3 product by use of AIRS total O_3.

How AIRS Total O_3 Can Complement OMI Total O_3

AIRS and OMI are both in A-train orbits

AIRS total O_3 can complement OMI for 3 reasons

- A small portion of the OMI scan line is missing because a piece of the thermal blanked obscured part of the FOV
- AIRS provides products both at 1:30 PM and 1:30 AM local time while OMI is 1:45 PM only

  AIRS provides twice daily coverage of rapidly travelling O_3 waves

- AIRS provides O_3 products during polar night

  This is a potentially huge benefit

For AIRS total O_3 products to be useful, they must be consistent with OMI total O_3 .

Gordon Labow started his investigation by comparing AIRS Version 6 total O_3 with OMI on select days. Gordon found that while the AIRS Version-6 total O_3 product was reasonably good compared to OMI, it had some significant limitations as well.

Version 6.X Improvements to Total O_3

Based on Gordon's findings, we made modifications to the O_3 profile retrieval step which improved the agreement of AIRS and OMI.

- *22 O_3 channels were added, including the strongest O_3 lines*
- *2 longwave (ℓw) spectral emissivity functions with hinge-points near 1000 cm^{-1} were added and solved for as part of both the ℓw emissivity and O_3 retrieval steps*
- *Ozone retrievals took into account the tropopause pressure*

Version 6.X´ contains minor further improvements in O_3 retrieval methodology – see next chart for Version 6.X´ channels.

Version 6.X retrievals were run at JPL for all of August 2013. Gordon Labow was very pleased with the new results, and showed Version 6.X results for August 2013 at the recent Aura Science Team Meeting. In this talk I will compare Version 6 and Version 6.X *q(p)* and total O_3 results for July 15, 2013 and then total O_3 results for August 2013.

Sample AIRS Cloud Free Brightness Temperature Spectrum
Version 6 Channels Indicated by ●

Version 6.X′ Channels Indicated by ●

● Ozone   ● ℓ w emissivity   ● ℓ w emissivity and Ozone

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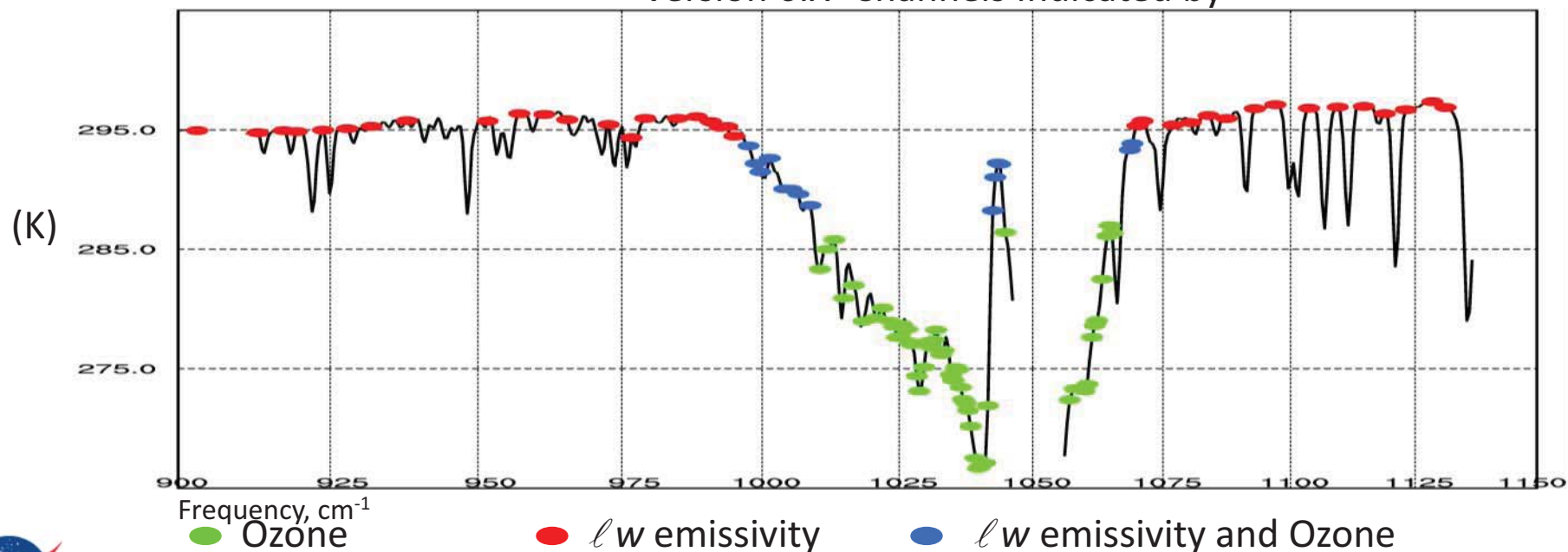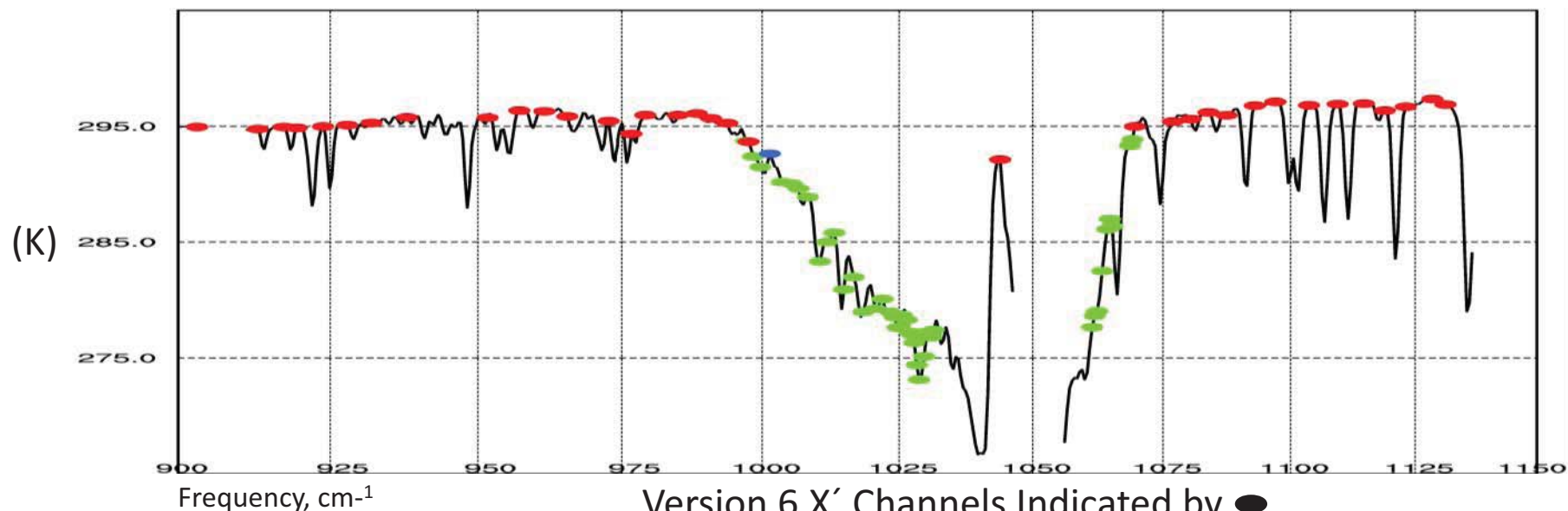
Global Water Vapor Profile July 15, 2013
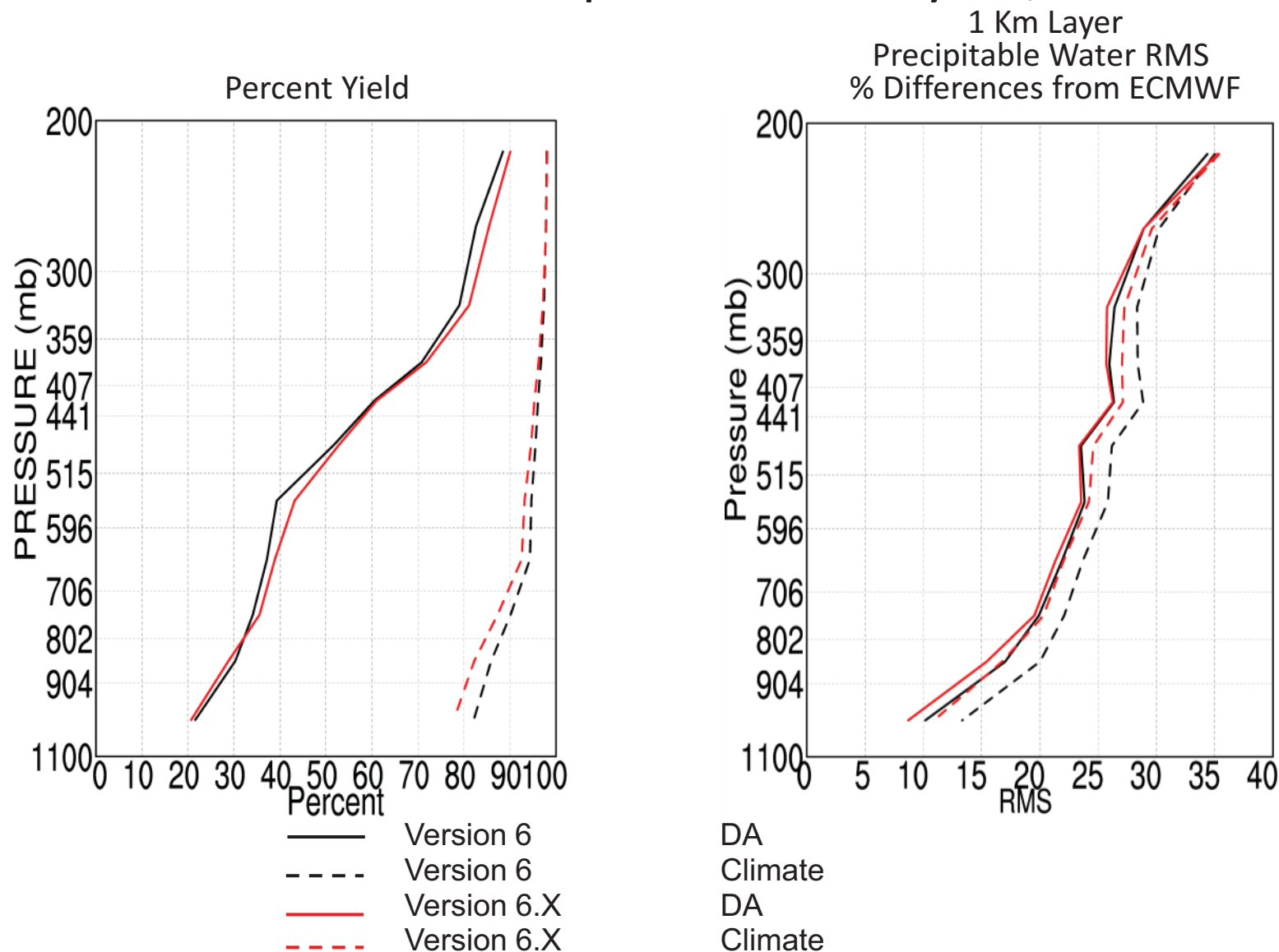
Accuracy with Climate QC has improved considerably over Version 6
Data Assimilation (DA) accuracy has also improved in lower troposphere.
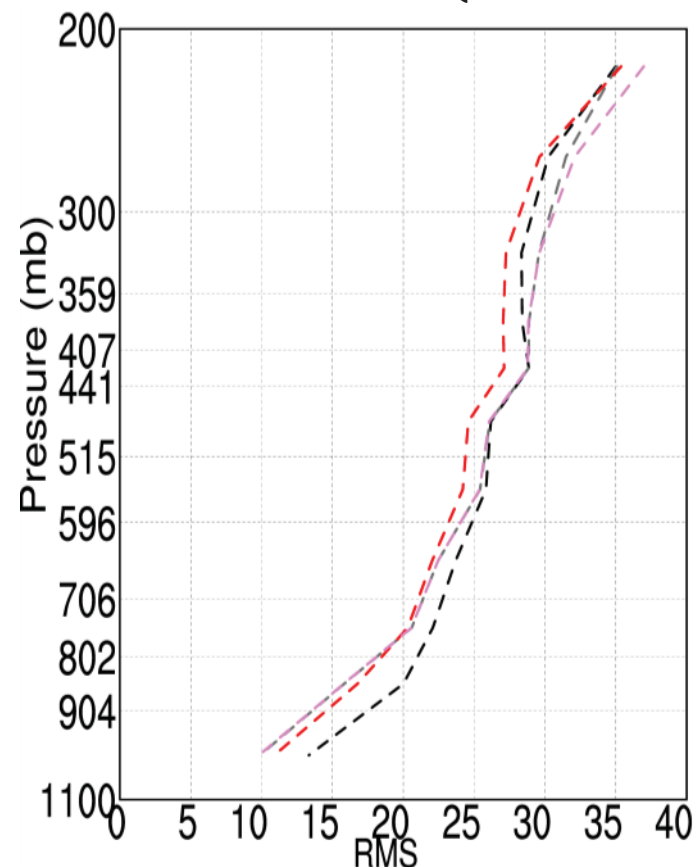
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Global Water Vapor Profile July 15, 2013

1 Km Layer Precipitable Water RMS
% Differences from ECMWF
Data Assimilation QC
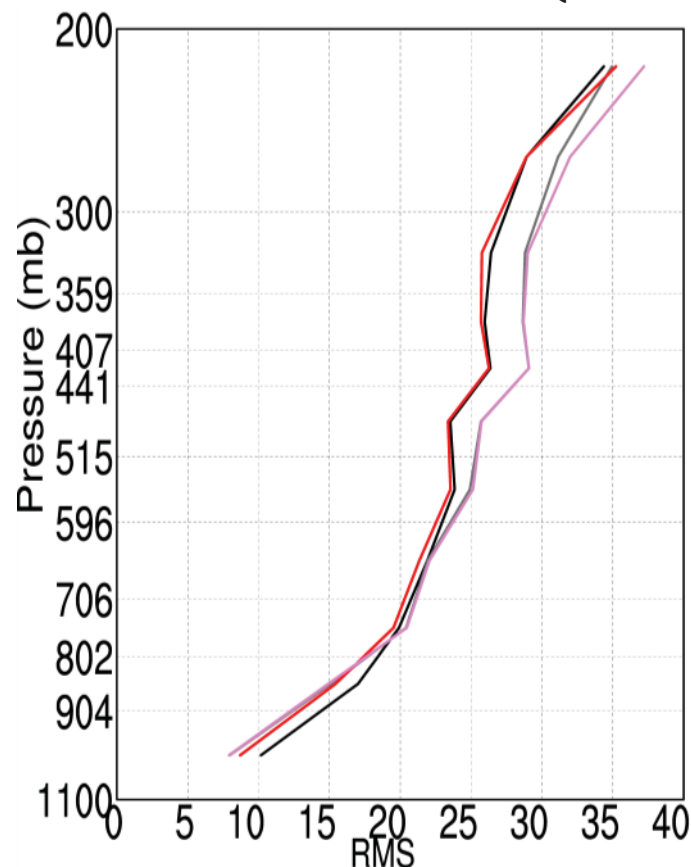
Legend (left):
— Version 6
— Version 6   Neural-Net
— Version 6.X
— Version 6.X   Neural-Net

1 Km Layer Precipitable Water RMS
% Differences from ECMWF
Climate QC

Legend (right):
- - - Version 6
- - - Version 6   Neural-Net
- - - Version 6.X
- - - Version 6.X   Neural-Net

Version 6.X retrieval no longer significantly degrades Neural-Net guess beneath 800 mb and improves Neural-Net guess above 800 mb with Climate QC.

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July 15, 2013   1:30 PM
Precipitable Water Surface to 850 mb (cm)

Version 6.X — a)
Global Mean = 1.26   STD= 0.75   %Filled= 75.70

Version 6 — b)
Global Mean = 1.21   STD= 0.75   %Filled= 76.96

Version 6.X minus ECMWF — c)
Global Mean = -0.01   STD= 0.14   Corr = 0.99
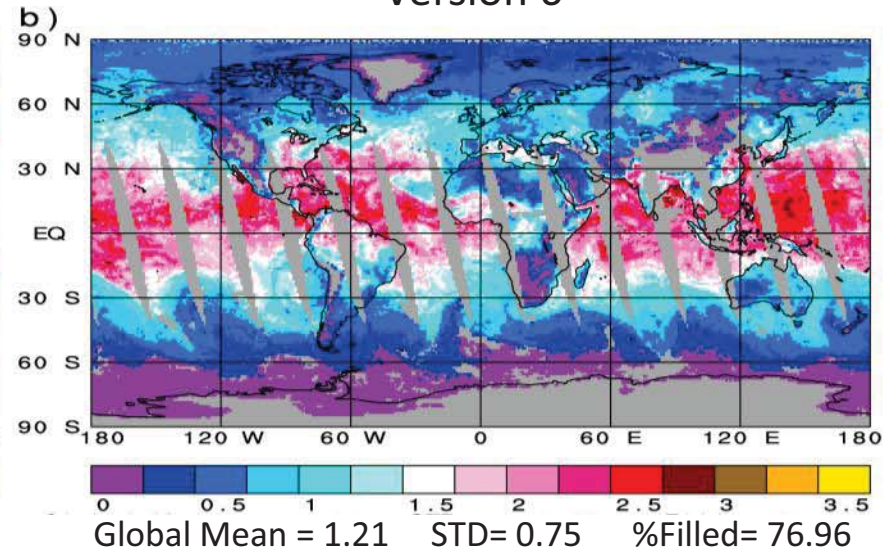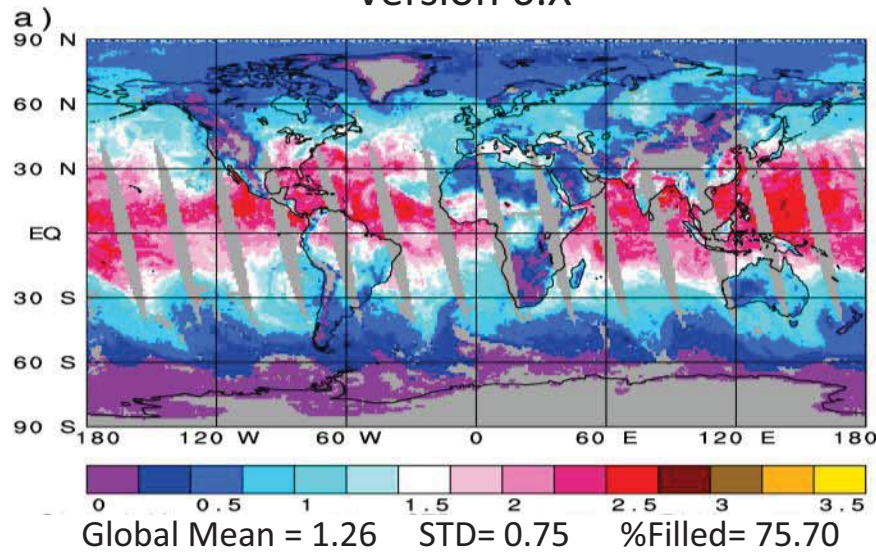
Version 6 minus ECMWF — d)
Global Mean = -0.05   STD= 0.18   Corr= 0.98
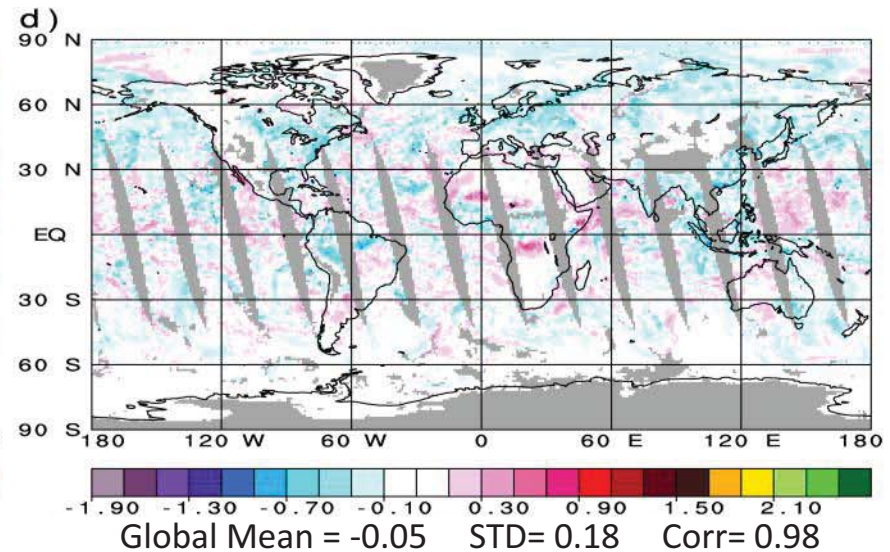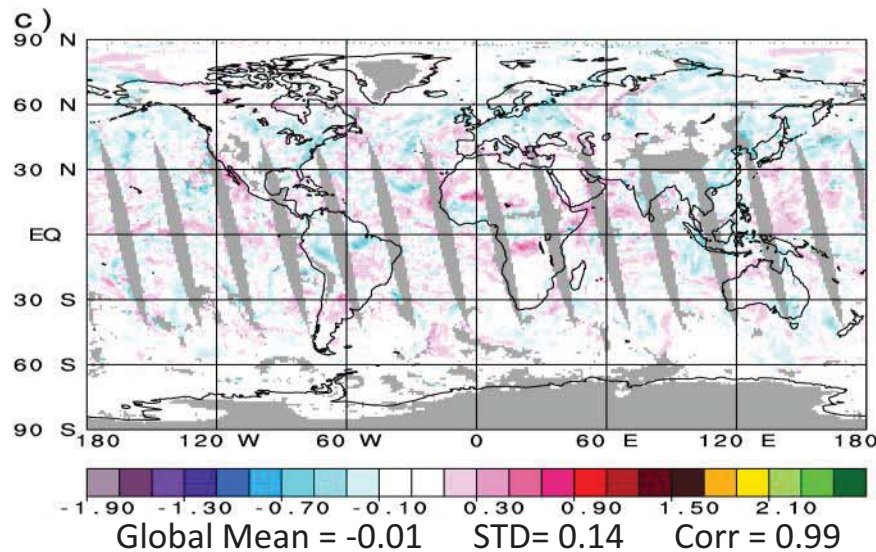
Version 6.X lower tropospheric water vapor is considerably improved compared to Version 6.

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July 15, 2013 1:30 PM
Precipitable Water 500 mb to top (mm*1000)

a) Version 6.X

Global Mean = 11.67   STD= 12.92   %Filled= 87.83

b) Version 6

Global Mean = 11.64   STD= 12.94   %Filled= 87.96
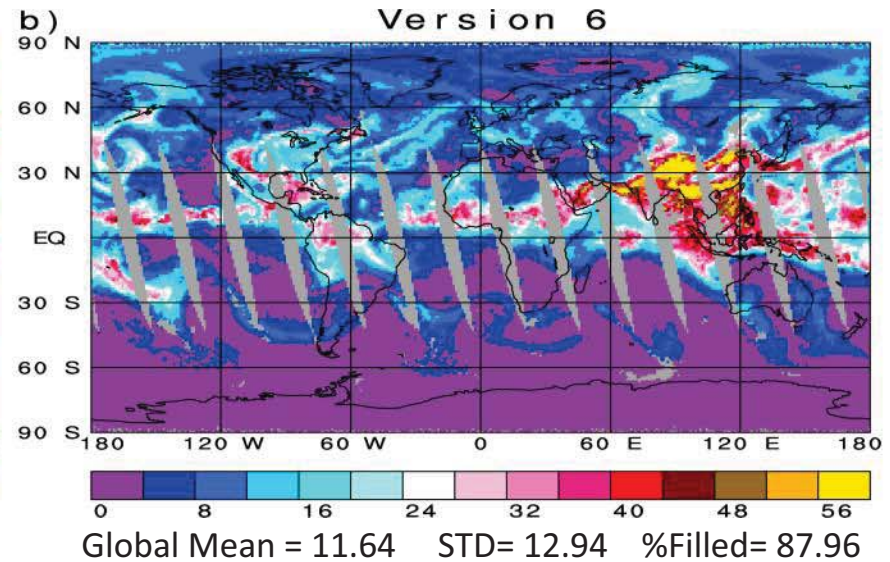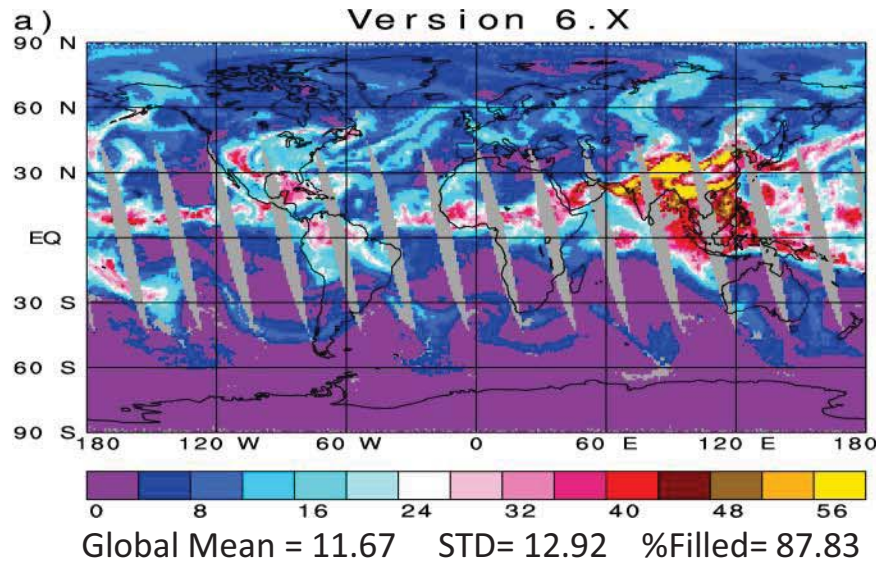
Precipitable Water 50 mb to top (mm*10000)

c) Version 6.X

Global Mean = 1.56   STD= 0.03   %Filled= 89.07

d) Version 6

Global Mean = 1.16   STD= 0.26   %Filled= 89.07
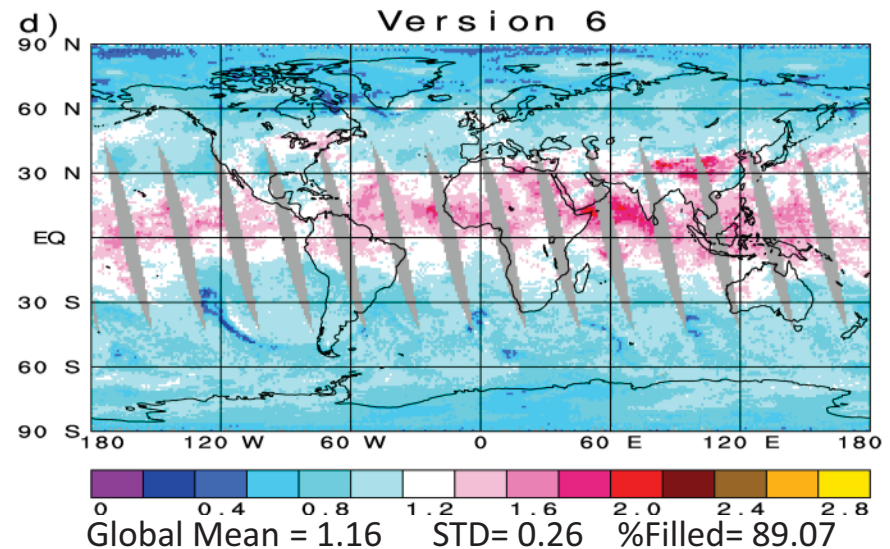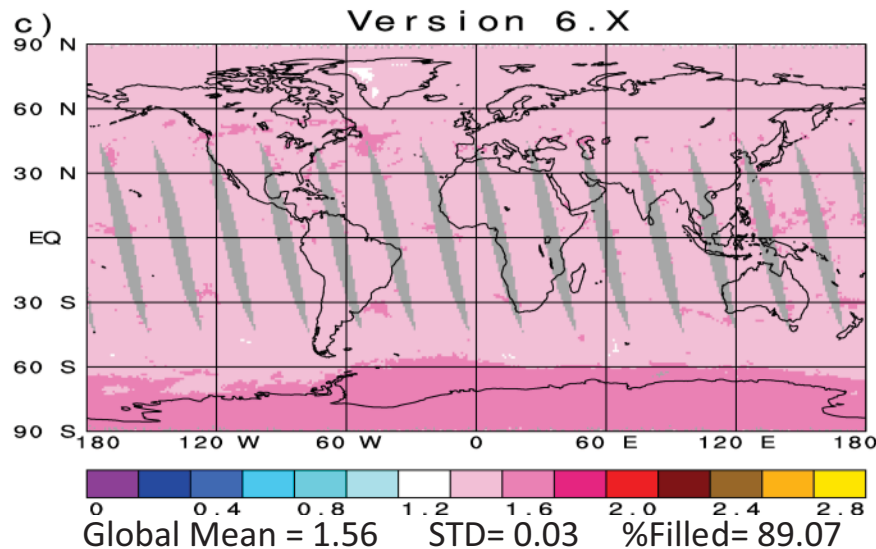
Version 6 shows erroneous tropospheric features in the upper stratospheric water vapor field. This has been corrected in Version 6.X.

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July 15, 2013   1:30 PM
Total Ozone (DU) Version 6

- The general features of Version 6 total O_3 match OMI reasonably well, especially the peaks and troughs of the travelling waves at mid-latitudes

Version 6 Limitations at 1:30 PM
- The amplitude of the O_3 travelling waves in AIRS is too large
- AIRS O_3 is too low over the warm oceanic pool
- AIRS O_3 is too high over most land areas
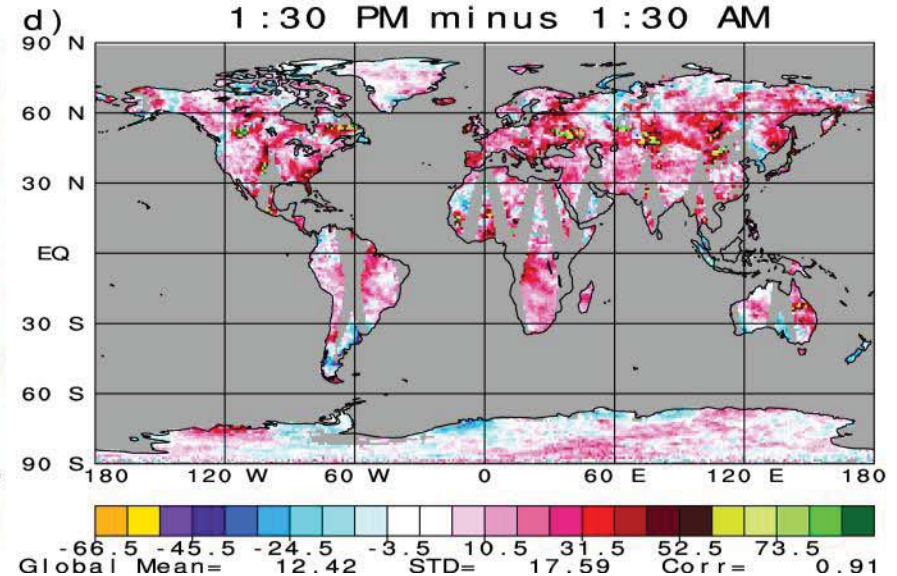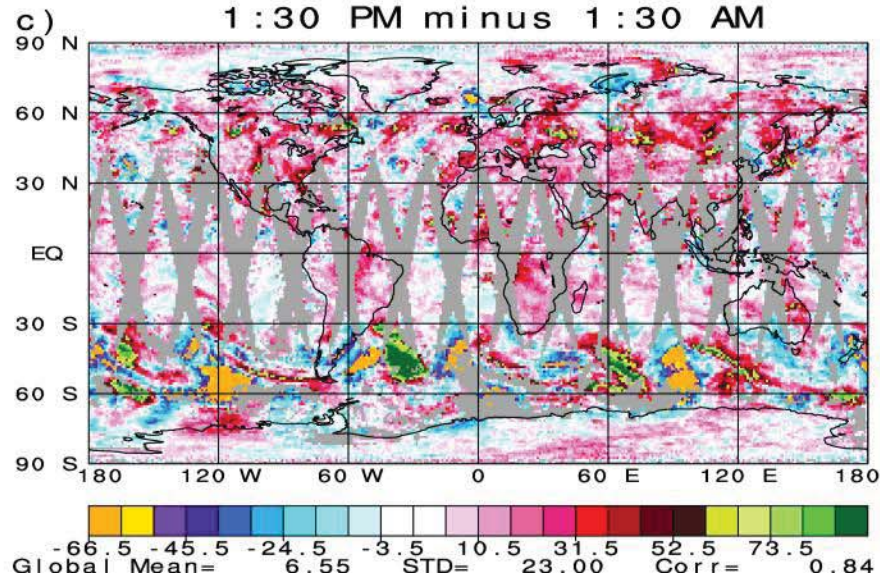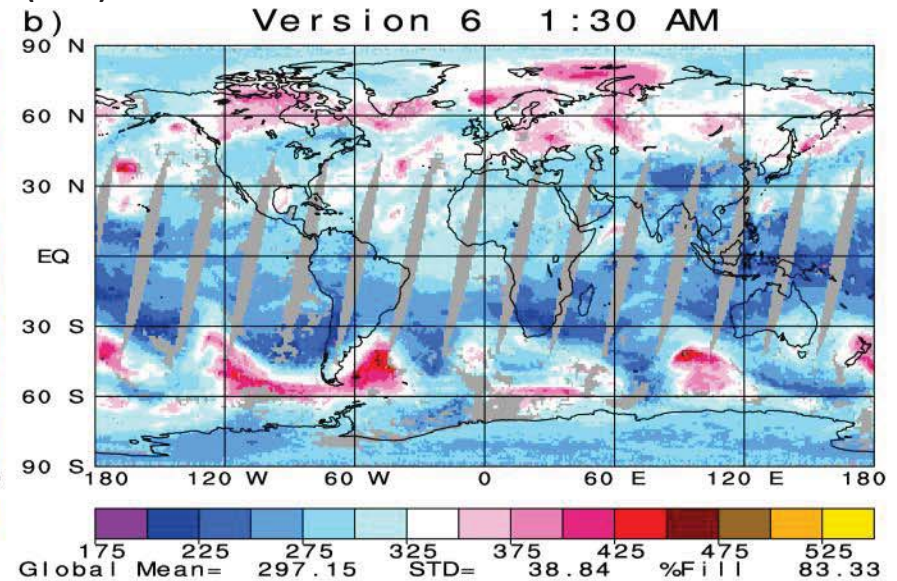
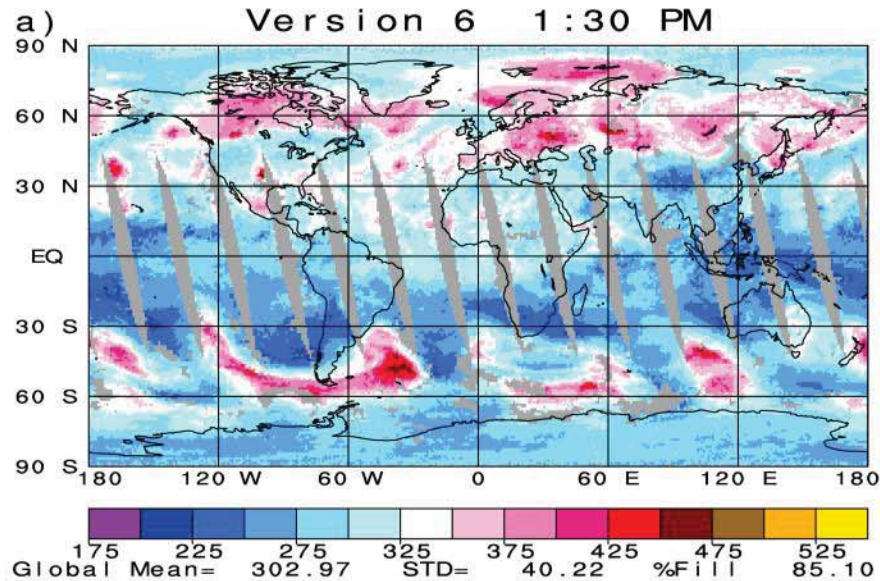July 15, 2013 1:30 AM
Total Ozone (DU) Version 6
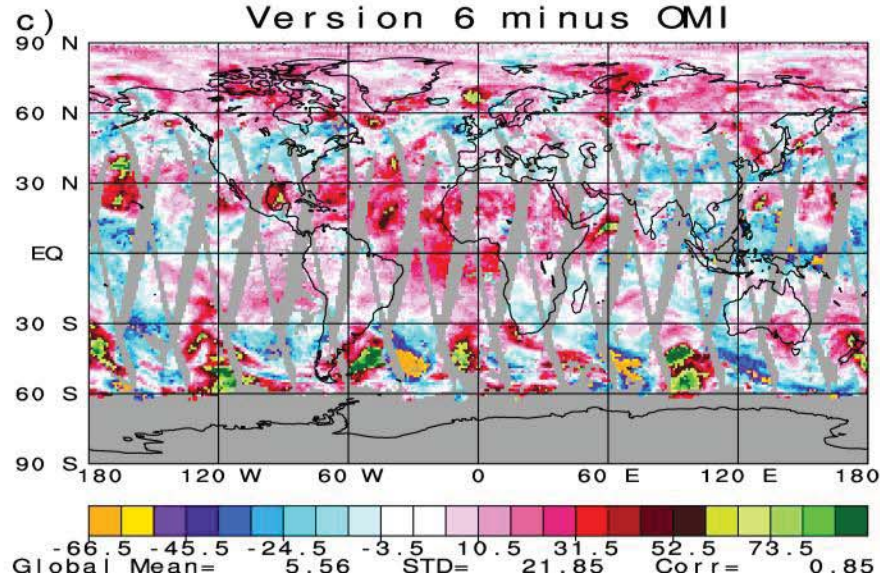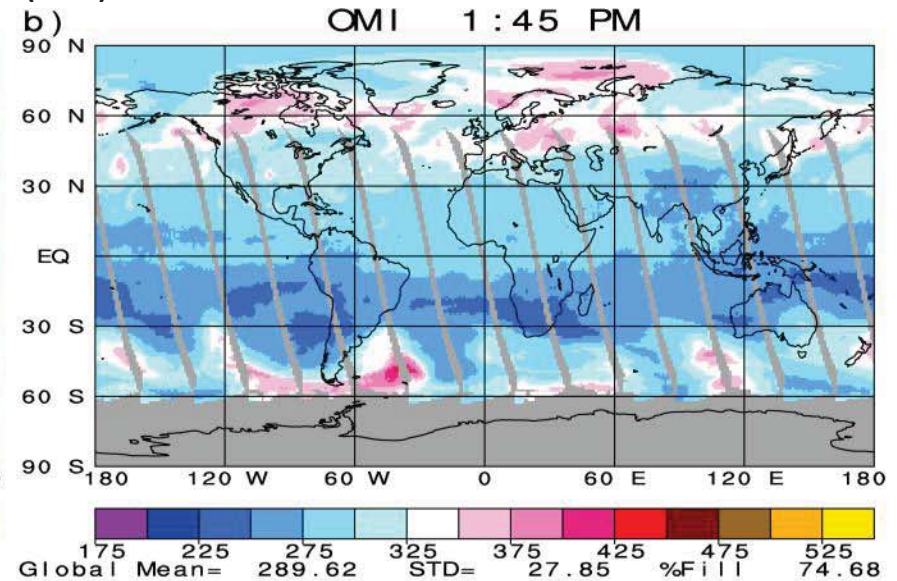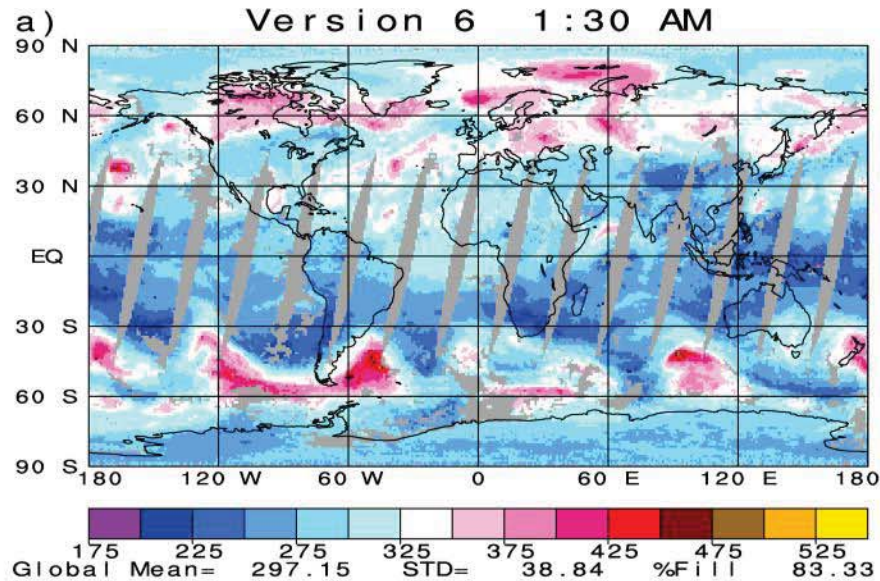
- O_3 results are again reasonably good
- Locations of travelling waves don't match because of large time differences

Limitations - As found at 1:30 PM

- The amplitude of AIRS O_3 waves is too large compared to OMI
- AIRS O_3 is too low over the oceanic warm pool
- AIRS O_3 over land is too high, but less so than at 1:30 PM

July 15, 2013   1:30 AM
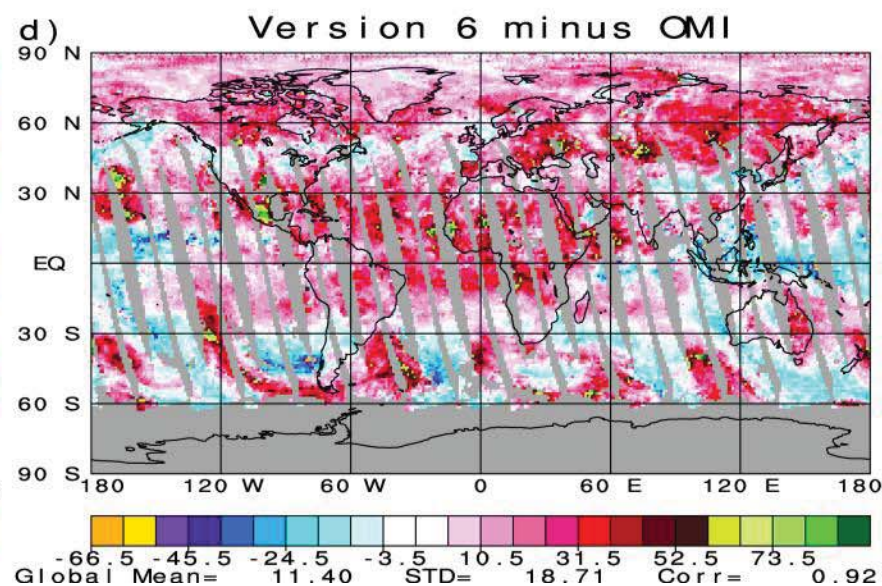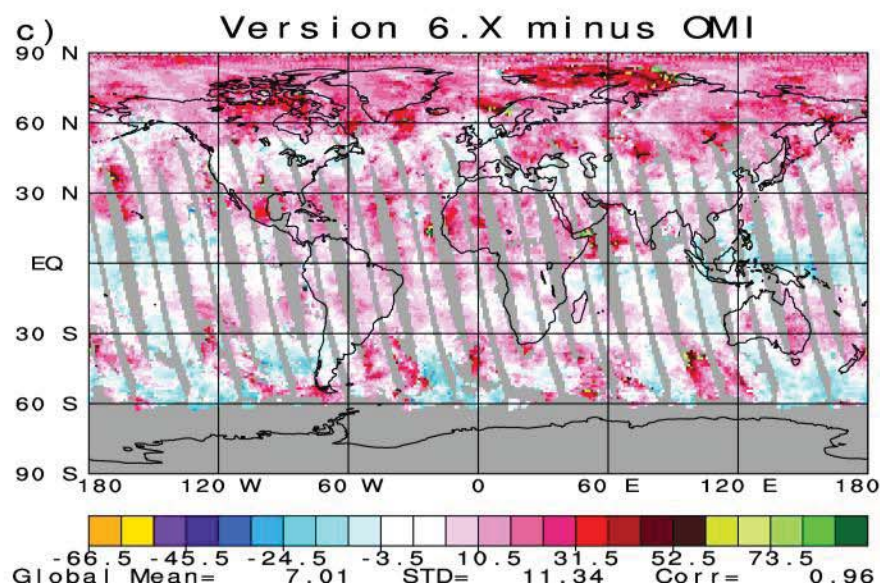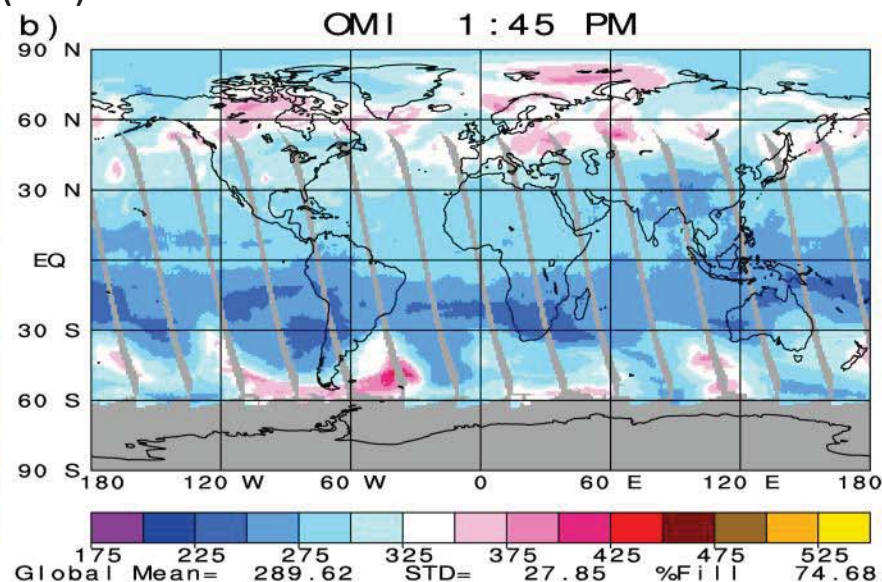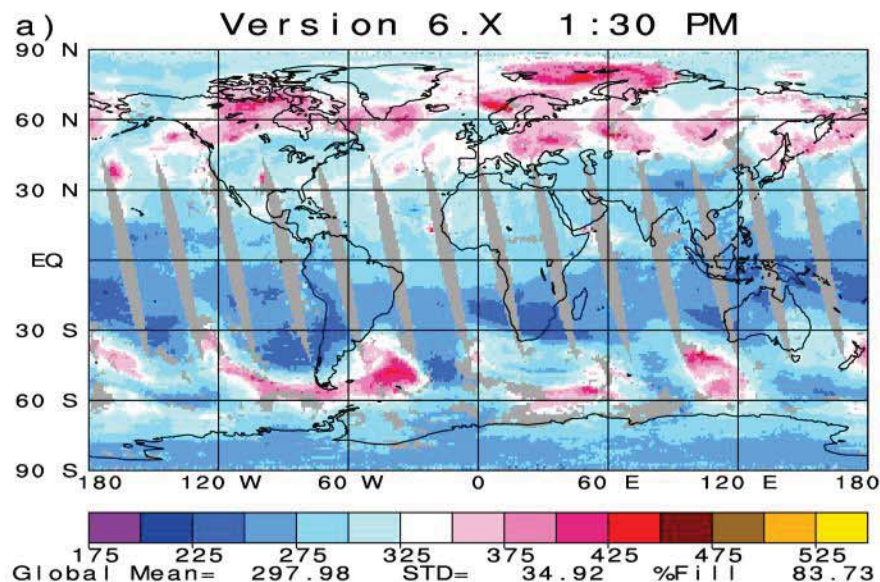Total Ozone (DU) Version 6

1:30 PM/AM differences are small over ocean except for travelling waves
1:30 PM/AM differences are large positive over land – this is an artifact.

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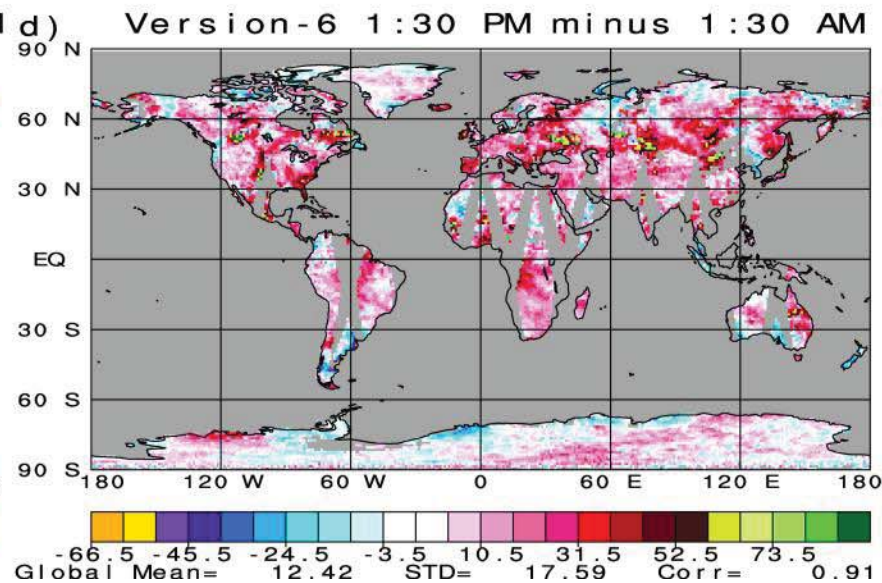July 15, 2013   1:30 PM
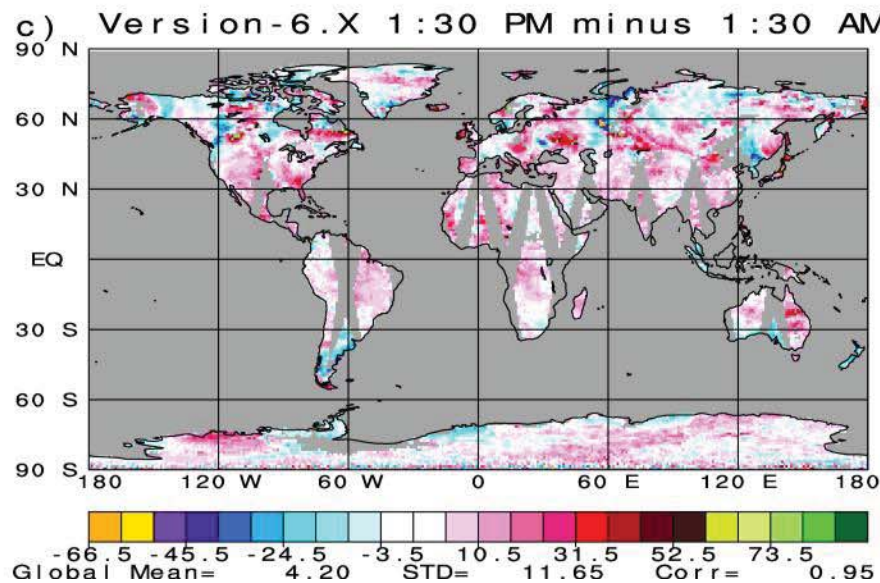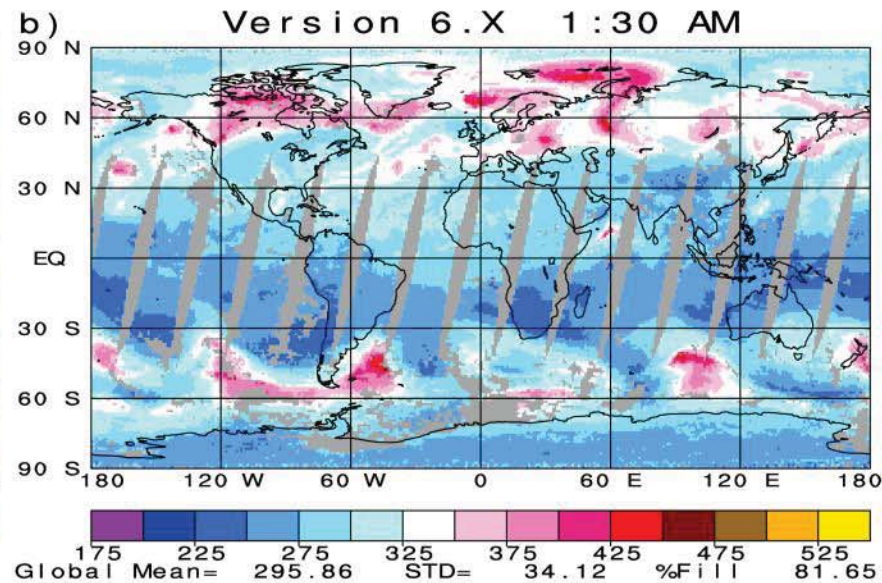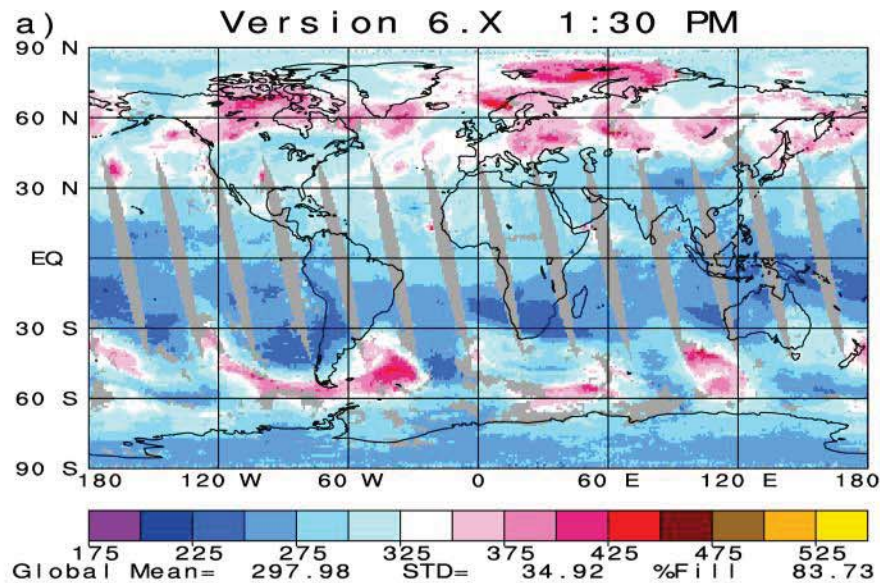Total Ozone (DU) Version 6.X

Version 6.X agrees much better with OMI than does Version 6 in terms of wave amplitude and biases in the oceanic warm pool and over land.
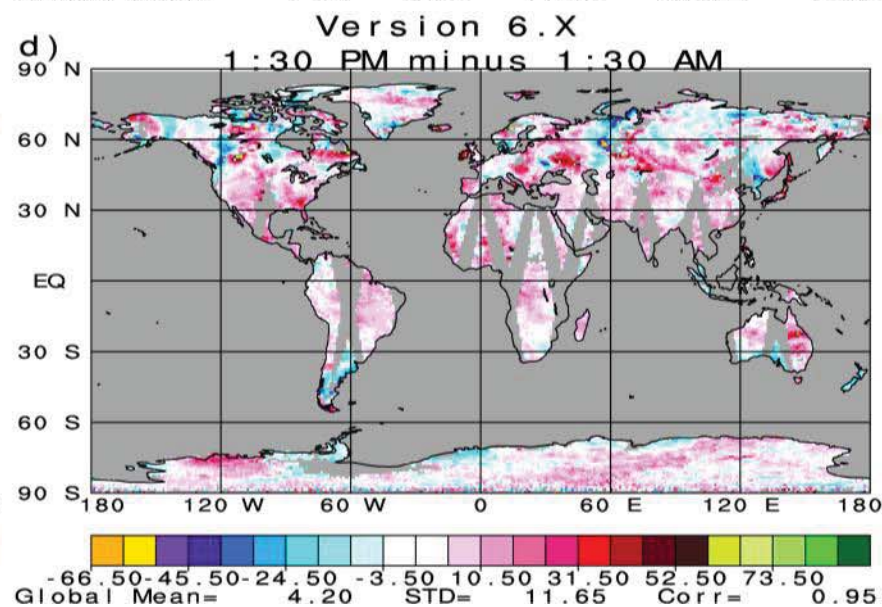
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July 15, 2013   1:30 AM
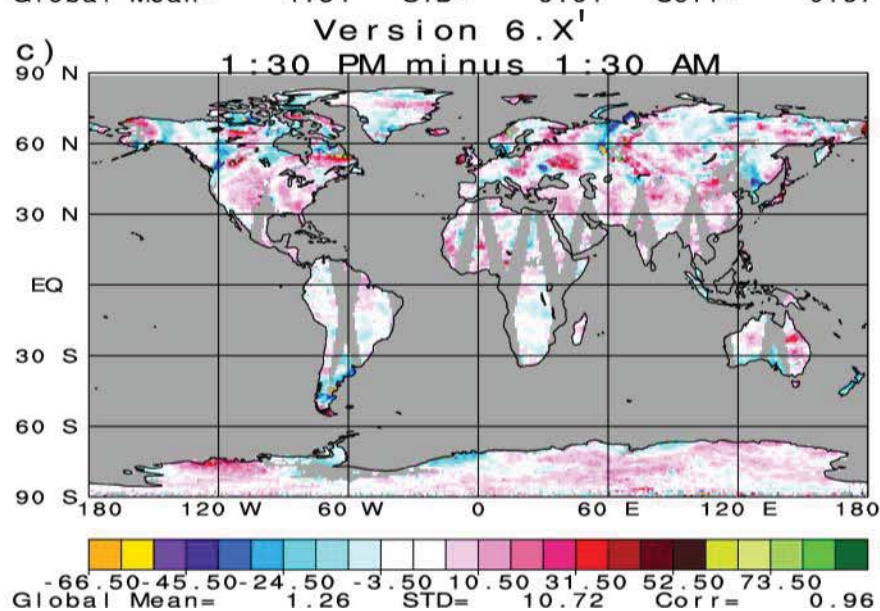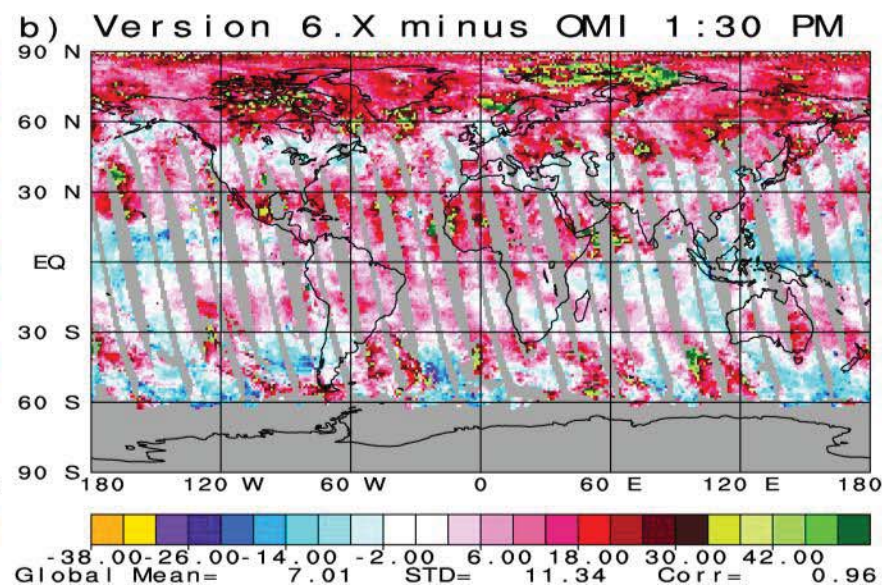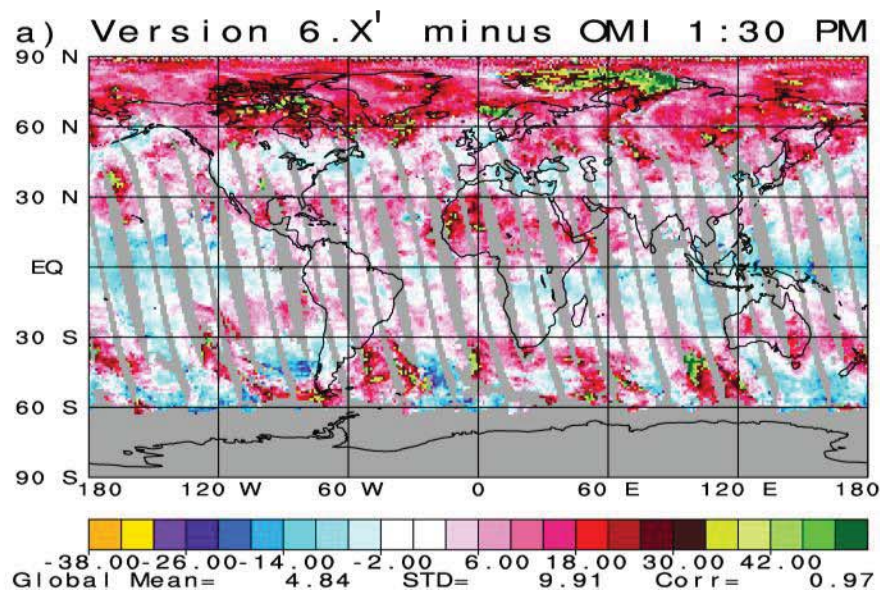## Total Ozone (DU) Version 6.X

Spurious PM/AM differences over land are much smaller in Version 6.X than in Version 6.

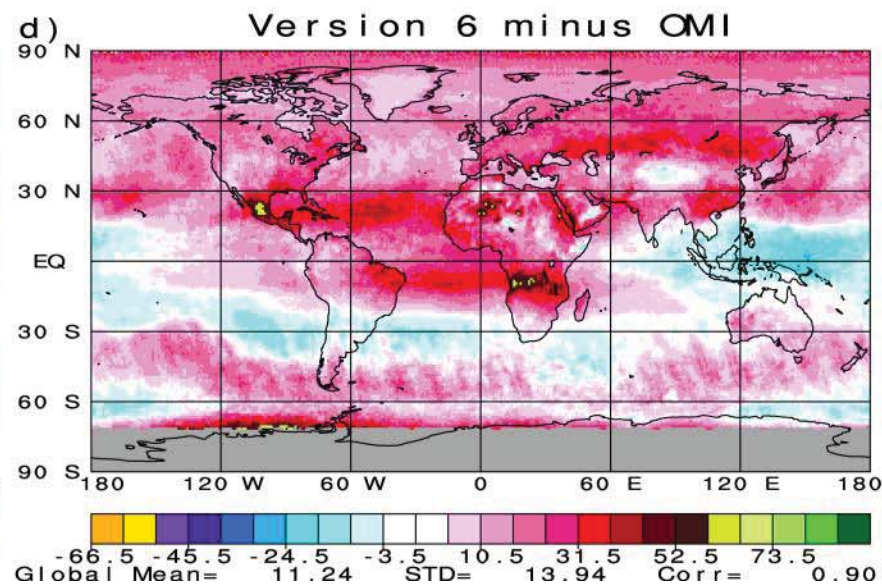Joel Susskind, John Blaisdell, Lena Iredell

Total Ozone (DU)   July 15, 2013

Version 6.X' total O$_3$ is further improved over Version 6.X both in terms of agreement with OMI and day/night differences over land

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Total Ozone (DU)
August 2013 Monthly Mean

a) Version 6.X   1:30 PM

Global Mean=   292.51   STD=   24.76   %Fill   100.00

b) OMI   1:45 PM

Global Mean=   287.76   STD=   21.91   %Fill   89.54

c) Version 6.X minus OMI

Global Mean=   6.02   STD=   7.20   Corr=   0.94

d) Version 6 minus OMI

Global Mean=   11.24   STD=   13.94   Corr=   0.90
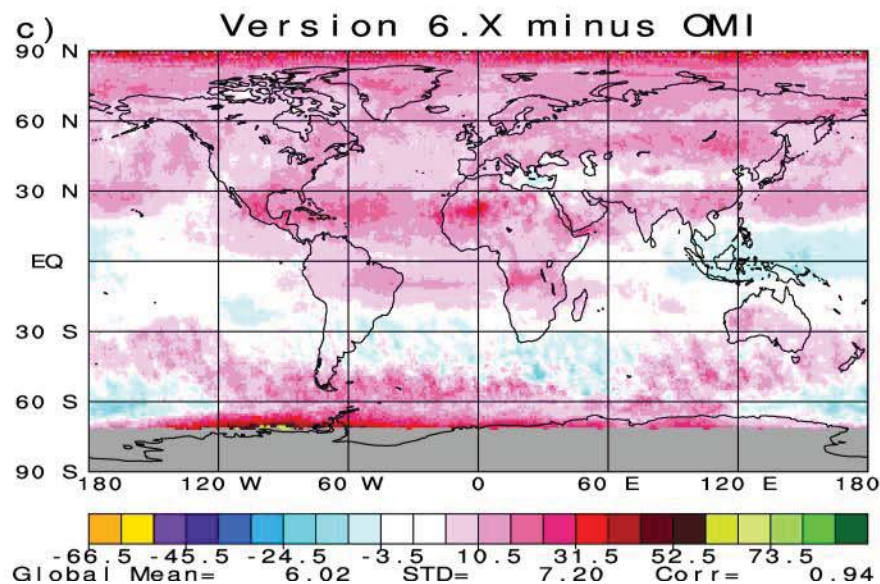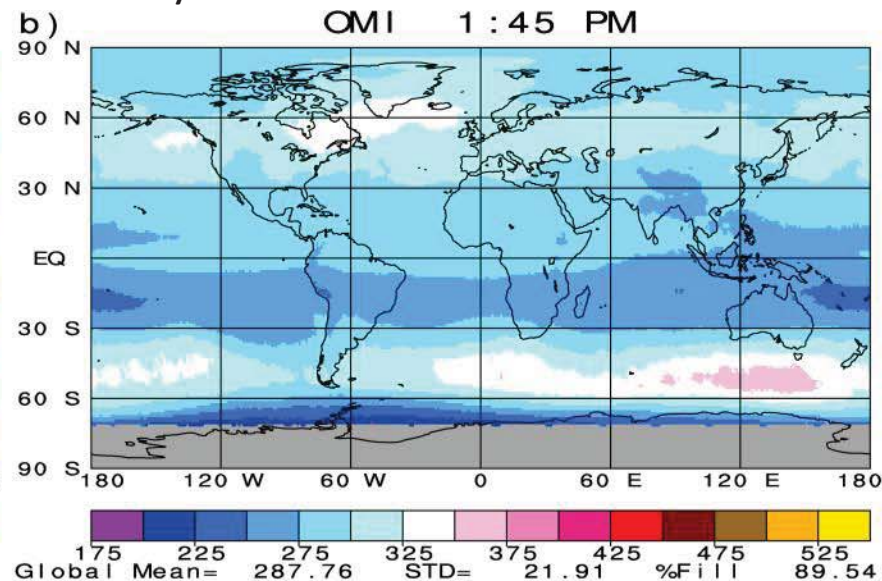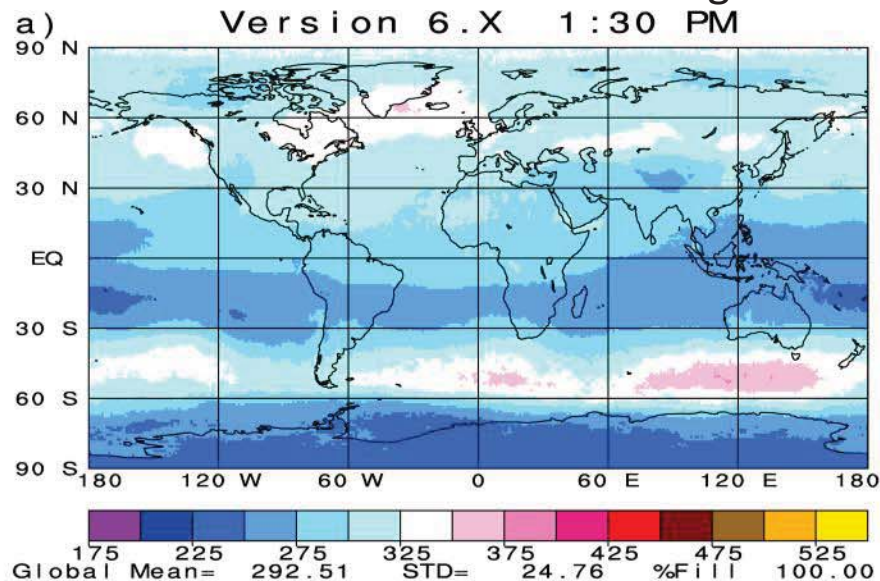
The pattern of Version 6.X differences from OMI at 1:30 PM is similar to that of Version 6, but all differences are much smaller.

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Total Ozone (DU)
August 2013 Monthly Mean
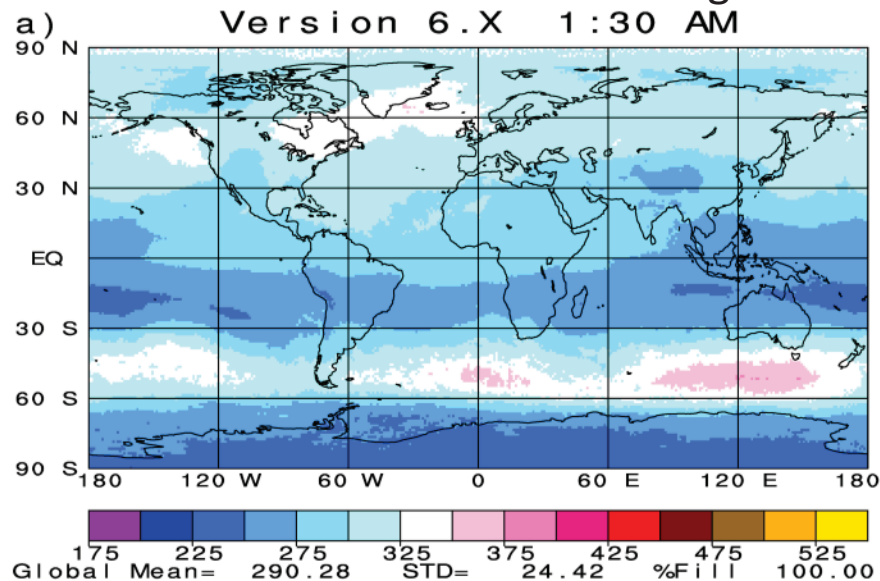
Analogous findings hold for total O_3 at 1:30 AM. Agreement with OMI is better at night than during the day in both Version 6.X and Version 6.

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Total Ozone (DU)
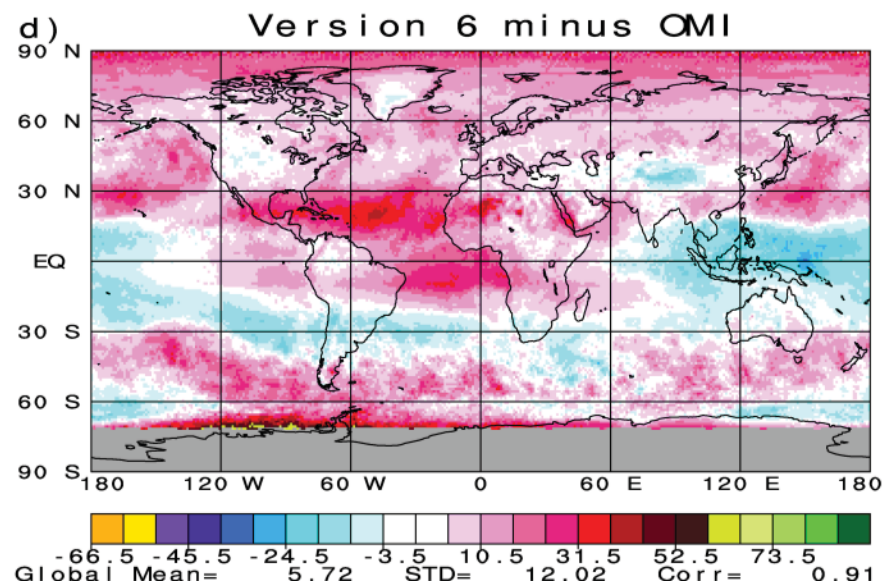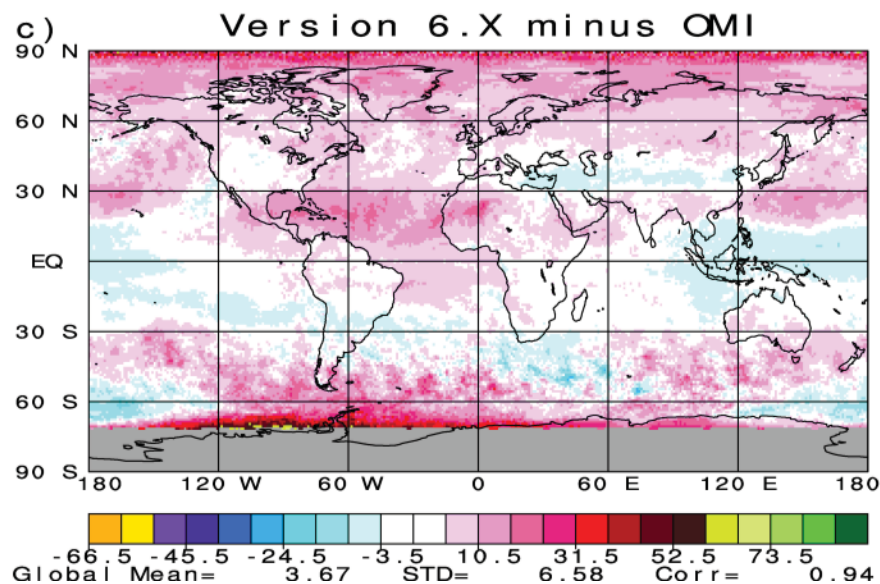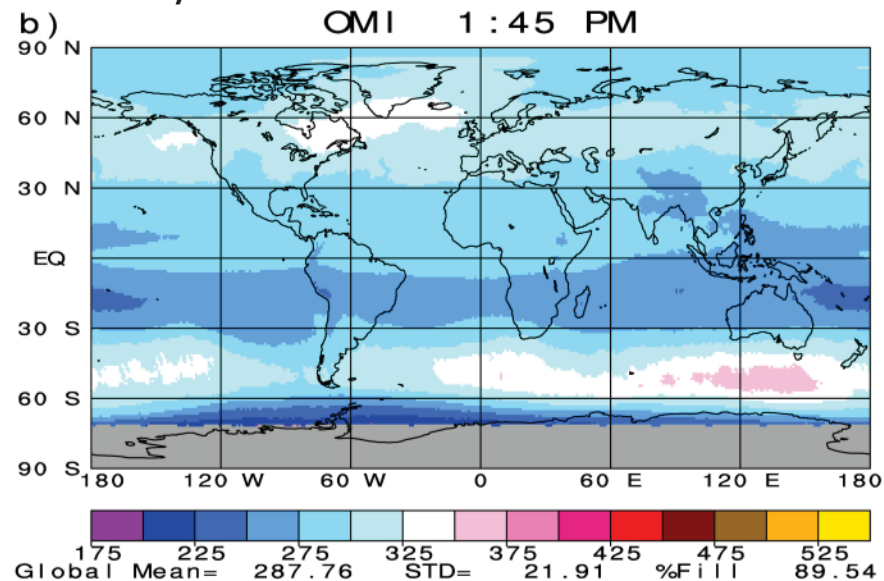## August 2013 Monthly Mean

a) Version 6.X 1:30 PM

Global Mean= 292.51 STD= 24.76 %Fill 100.00

b) Version 6.X 1:30 AM

Global Mean= 290.28 STD= 24.42 %Fill 100.00

c) Version 6.X 1:30 PM minus 1:30 AM

Global Mean= 2.24 STD= 4.46 Corr= 0.99

d) Version 6 1:30 PM minus 1:30 AM

Global Mean= 5.31 STD= 7.33 Corr= 0.97
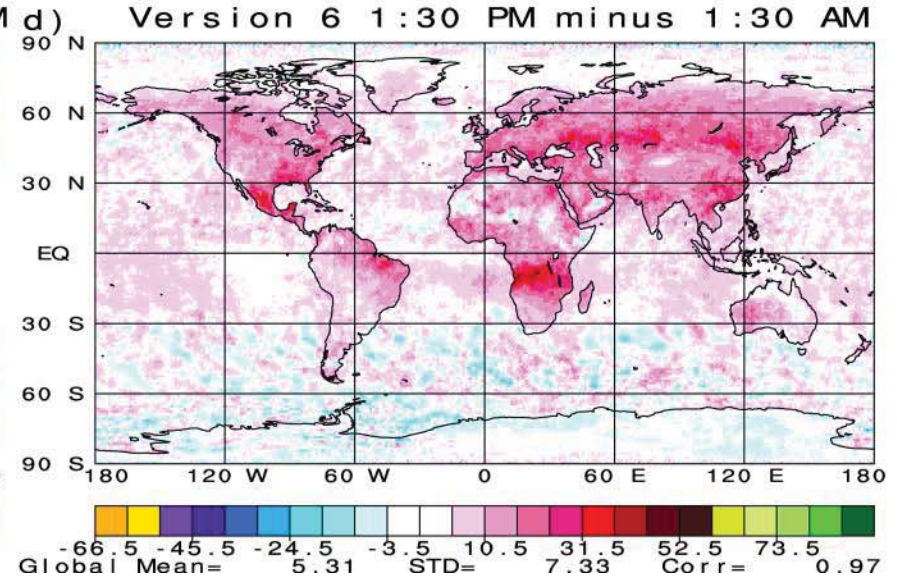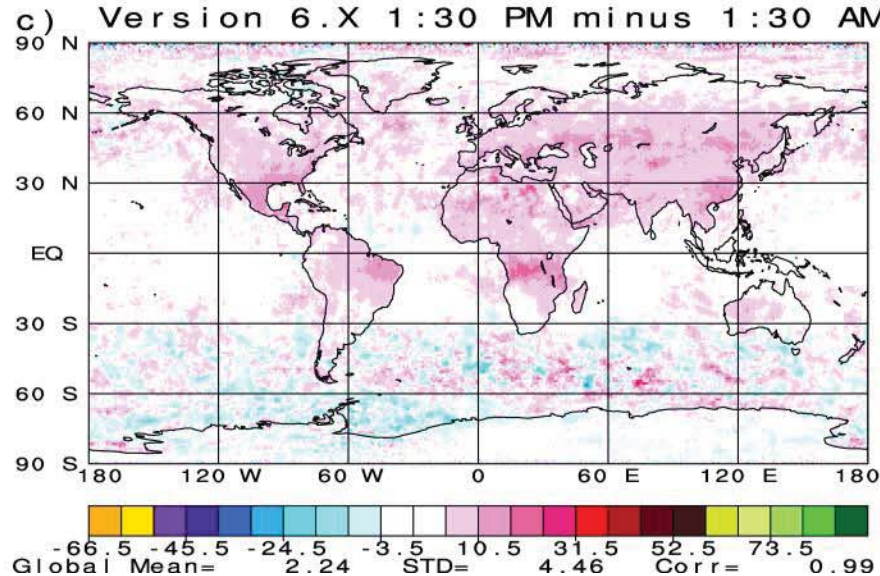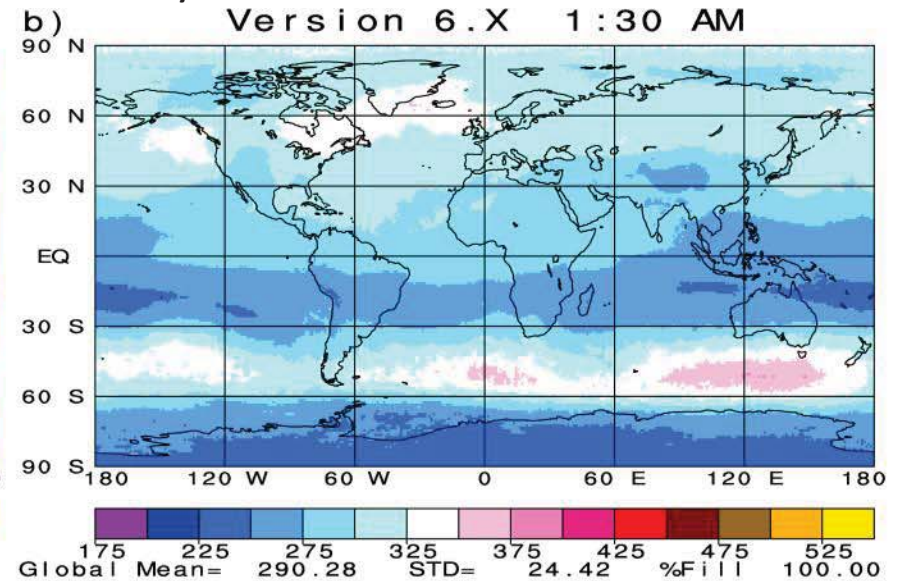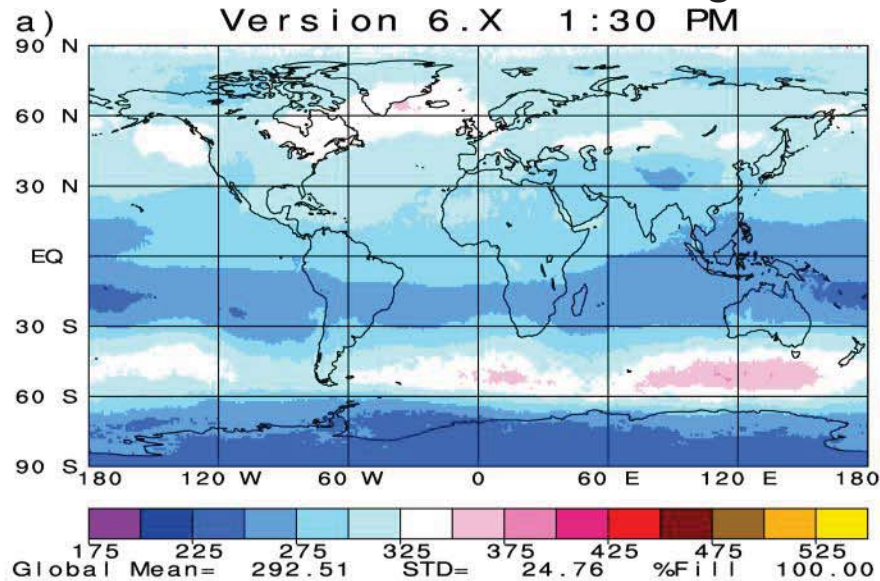
1:30 PM total O_3 values are more positive than 1:30 AM total O_3 values, especially over land, but by a reduced amount in Version 6.X.

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Summary

SRT Version 6.X is otherwise like Version 6, but contains some modifications, primarily in the water vapor and ozone profile retrieval steps, which had not been changed since Version 5.

The water vapor profile has improved significantly in Version 6.X, especially in the boundary layer.

Version 6.X total O_3 matches that of OMI much better than that of Version 6, which was already reasonably good. The improvements in O_3 retrieval methodology made in Version 6.X greatly reduced the magnitude of all monthly mean discrepancies between Version 6 total O_3 and OMI total O_3.

AIRS total O_3 agrees better with OMI over land at 1:30 AM than at 1:30 PM. This might be the result of a small error in land skin temperature during the day, or a result of higher sensitivity to emissivity errors when the surface is hot.

Availability of Version 6.X

The following data periods have been processed at JPL by John Blaisdell using Version 6.X: At the initial request of Gordon Labow, we processed August 2013 and the 15th of every month in 2013. He subsequently requested that we also analyze data for August 23 and 24 of 2014, because OMI showed very low values of total O_3 over Antarctica. John Blaisdell processed the whole time period August 15-31, 2014.

All level 2 and level 3 data are accessible on the AIRS cluster at JPL at /raid14/blaisdell/ozone1/.

We encourage all team members to examine the Version 6.X products to assess the extent, if any, that Version 6.X enhances their research interests as compared to Version 6. Does the team recommend that Version 6.X be brought up, with possible slight modification, as the current official JPL build?

Total O_3 on August 24, 2014

OMI showed very low values of total O_3 on this day in two nearby, but non-contiguous, regions near 70°S.
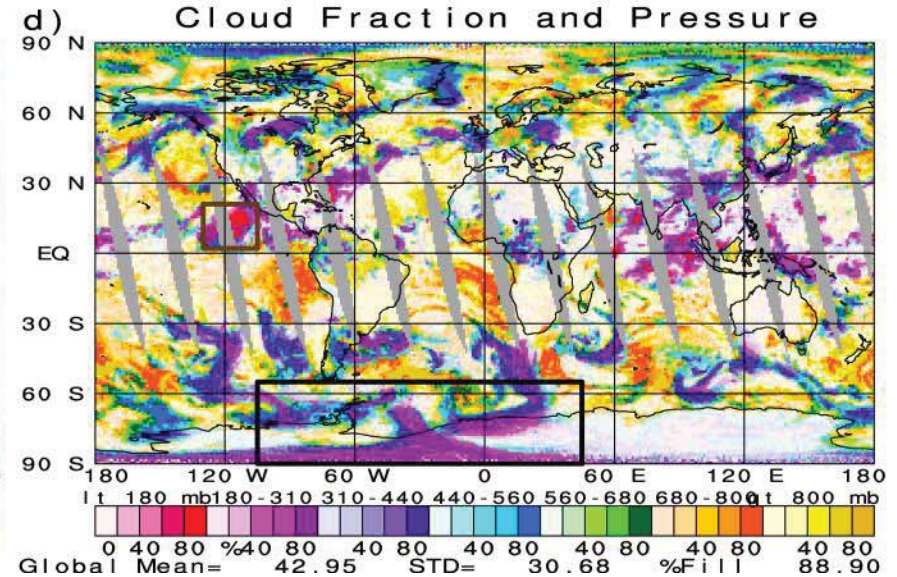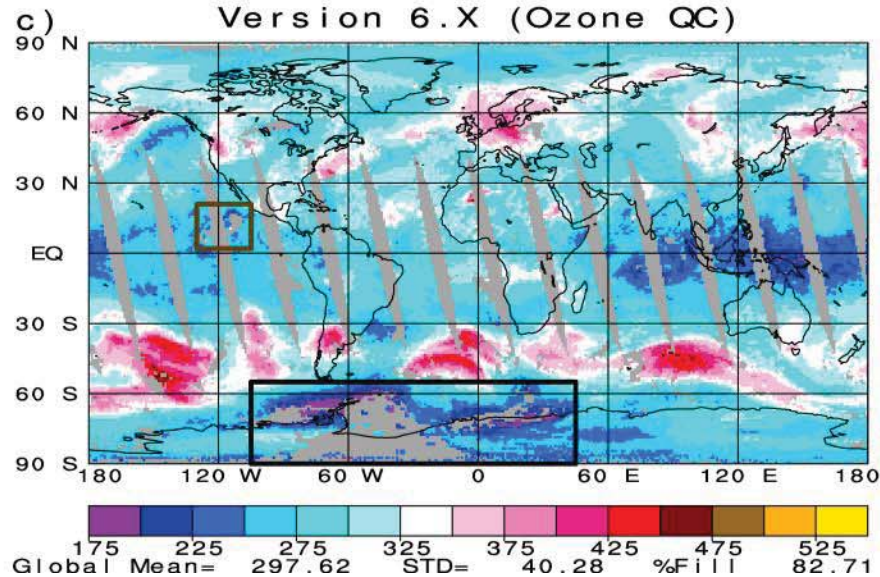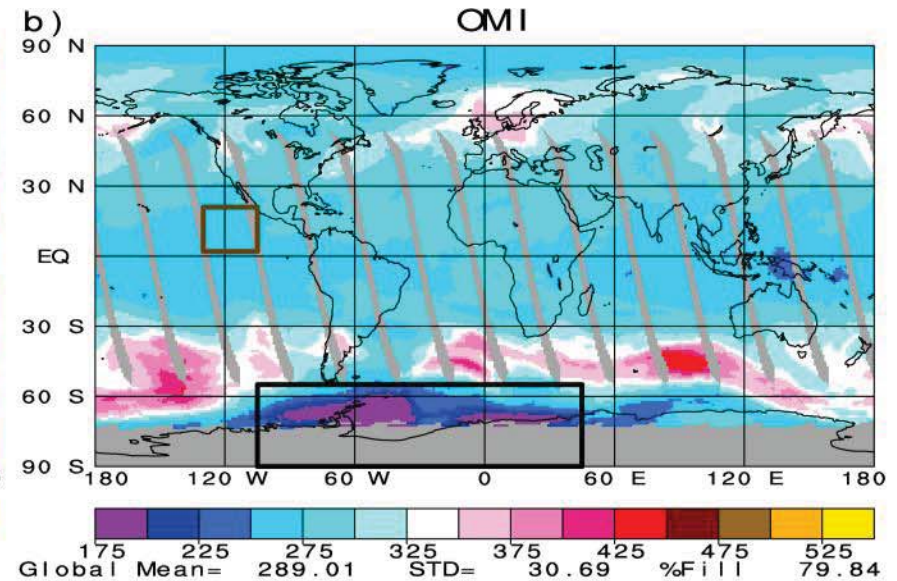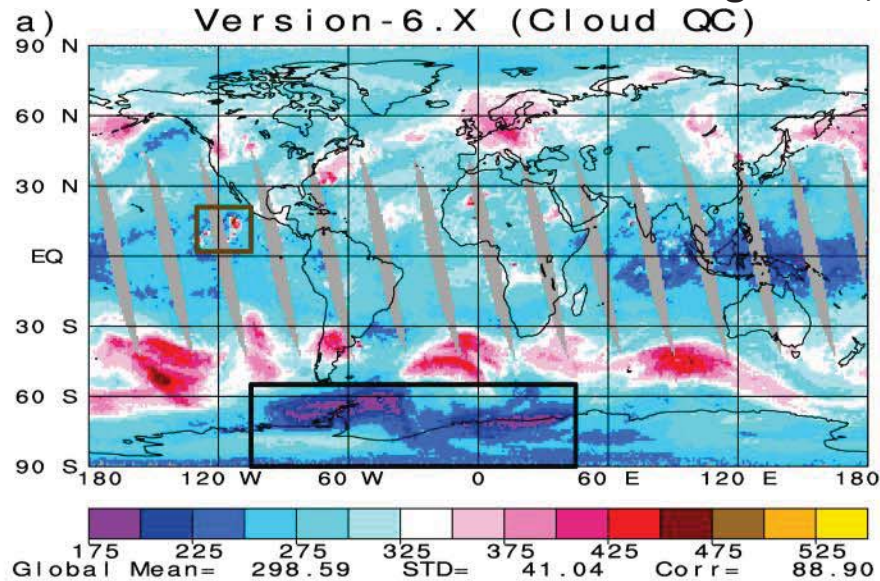
AIRS Version 6.X also showed low values of total O_3 in these areas, but O_3 retrievals in many local grid points were rejected by the O_3 QC flag, which flagged total O_3 as good quality only if $T(p)$ is flagged as good down to the surface.

Lena Iredell suggested that we examine, as a starting point, use of the cloud QC flag for total O_3, which would increase spatial coverage. This is a reasonable approach because most of the ozone is in the stratosphere. Use of cloud QC for O_3 alleviated the problem near Antarctica, but introduced some spurious values in the tropics where it is raining heavily. We are examining QC options for total O_3.

The next chart shows excellent agreement between AIRS and OMI over Antarctica using cloud QC, and depicts a small tropical region where previously rejected spurious values of total O_3 are now accepted.

Total Ozone (DU)
August 24, 2013   1:30 PM

a) Version-6.X (Cloud QC)

Global Mean= 298.59   STD= 41.04   Corr= 88.90

b) OMI

Global Mean= 289.01   STD= 30.69   %Fill 79.84

c) Version 6.X (Ozone QC)

Global Mean= 297.62   STD= 40.28   %Fill 82.71

d) Cloud Fraction and Pressure

Global Mean= 42.95   STD= 30.68   %Fill 88.90

Black line ——— encloses area in which Cloud QC adds good O_3 retrievals
Brown line ——— encloses area in which Cloud QC adds spurious O_3 retrievals

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SRT Short Term Plans

SRT plans to conduct retrieval and QC optimization studies (channels, functions, damping) with the goal of making further improvement in many retrieval products. This retrieval system, Version 6.Y, will contain potential improvements in retrievals of T_{skin}, $T(p)$, and cloud parameters, as well as in $q(p)$ and $O_3(p)$.

We intend to finalize these studies and implement Version 6.Y at JPL for testing before the Spring 2015 Science Team meeting. SRT welcomes improvements from other Team members for possible inclusion in Version 6.Y.

We would like the Science Team to evaluate results of Version 6.Y and make a recommendation at the Fall 2015 meeting as to whether Version 6.Y, or a variation of it, should be used in the reprocessing of all AIRS data.